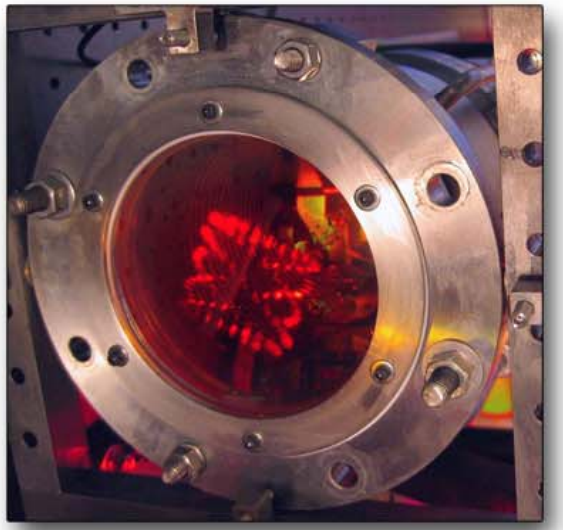
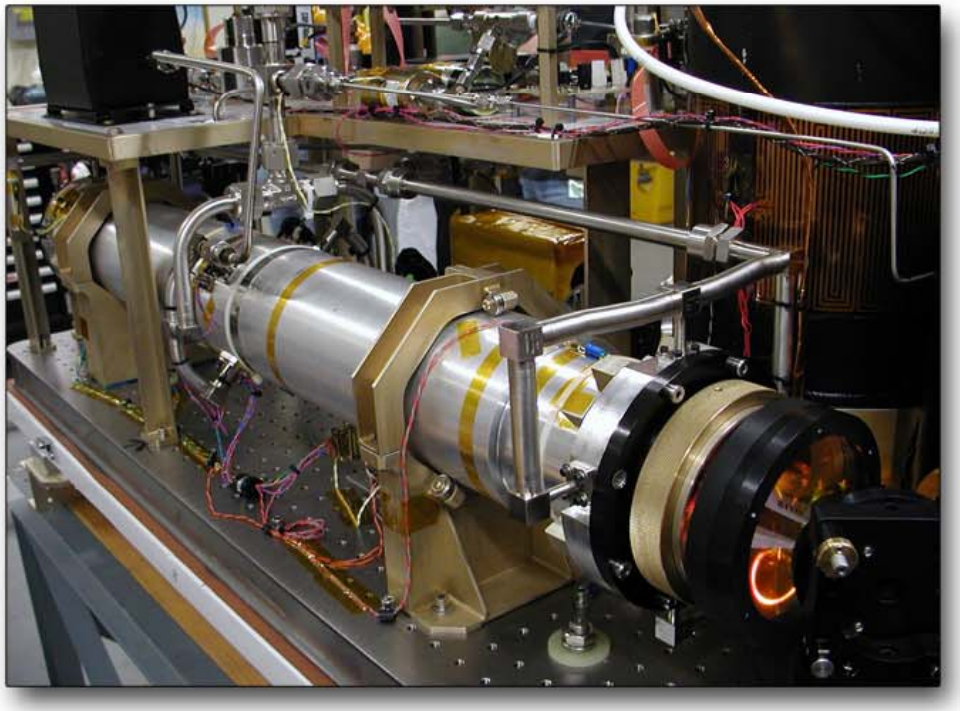
In-situ measurement of water vapor isotopic composition near the tropopause:

first results from the Harvard ICOS Isotope Instrument

Keutsch, F.N., Moyer, E.J., Sayres, D.S., Allen, N.T. Anderson, J.G.

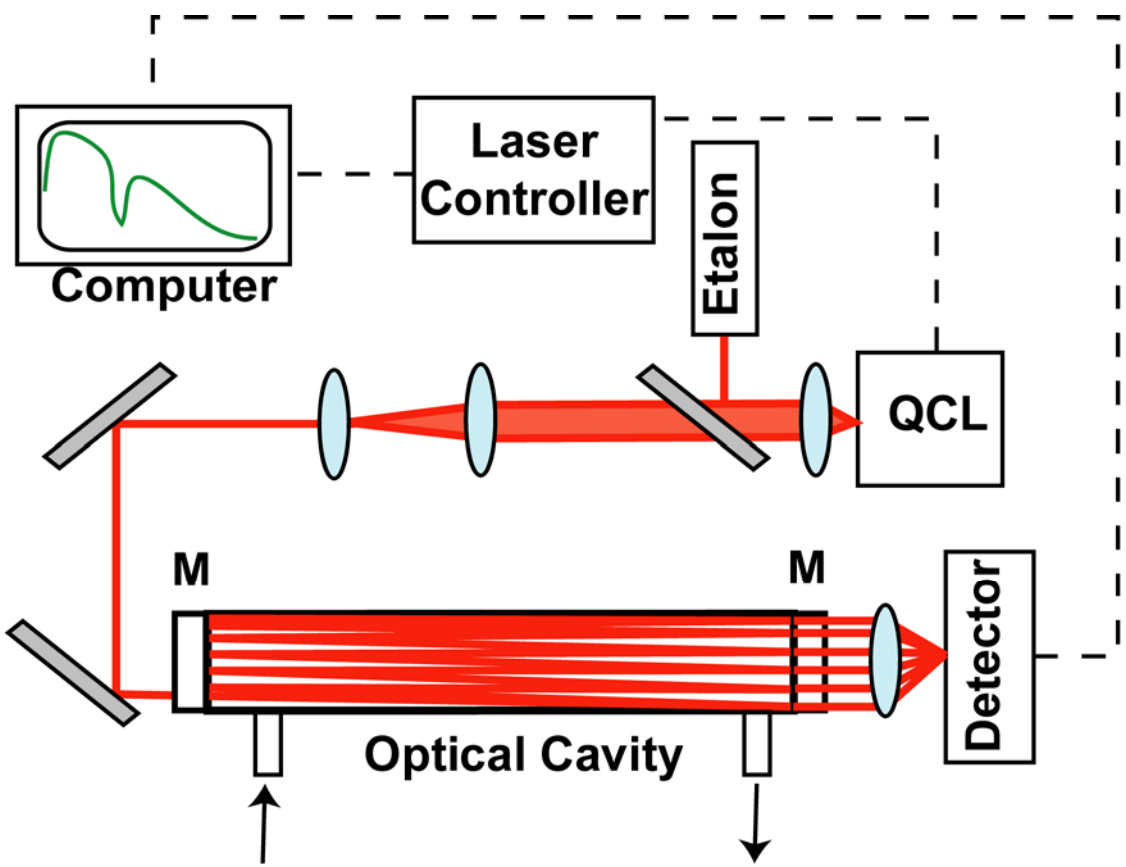




Water Isotopologues: Motivation

- Study of dehydration mechanisms (response to forcing)
- Priority 1 measurement for upcoming science missions
- Development need has been identified
  - Instrument for vapor phase is needed
  - Science requirements demand improved sensitivity
- Direct absorption:
  - simultaneous measurement of H_2O, HDO, $H_2{}^{18}O$
- **Substantial pathlength enhancement:**
  - **Integrated Cavity Output Spectroscopy (ICOS): > 4km pathlength**

Integrated Cavity Output Spectroscopy (ICOS)



$$\frac{dI}{dt} = T \times P - I\frac{c(1-R+\alpha \times L)}{L}$$

$$I_{SS} = \frac{PTL}{c(1-R+\alpha \times L)}$$

$$\tau = \frac{L}{c(1-R+\alpha \times L)}$$

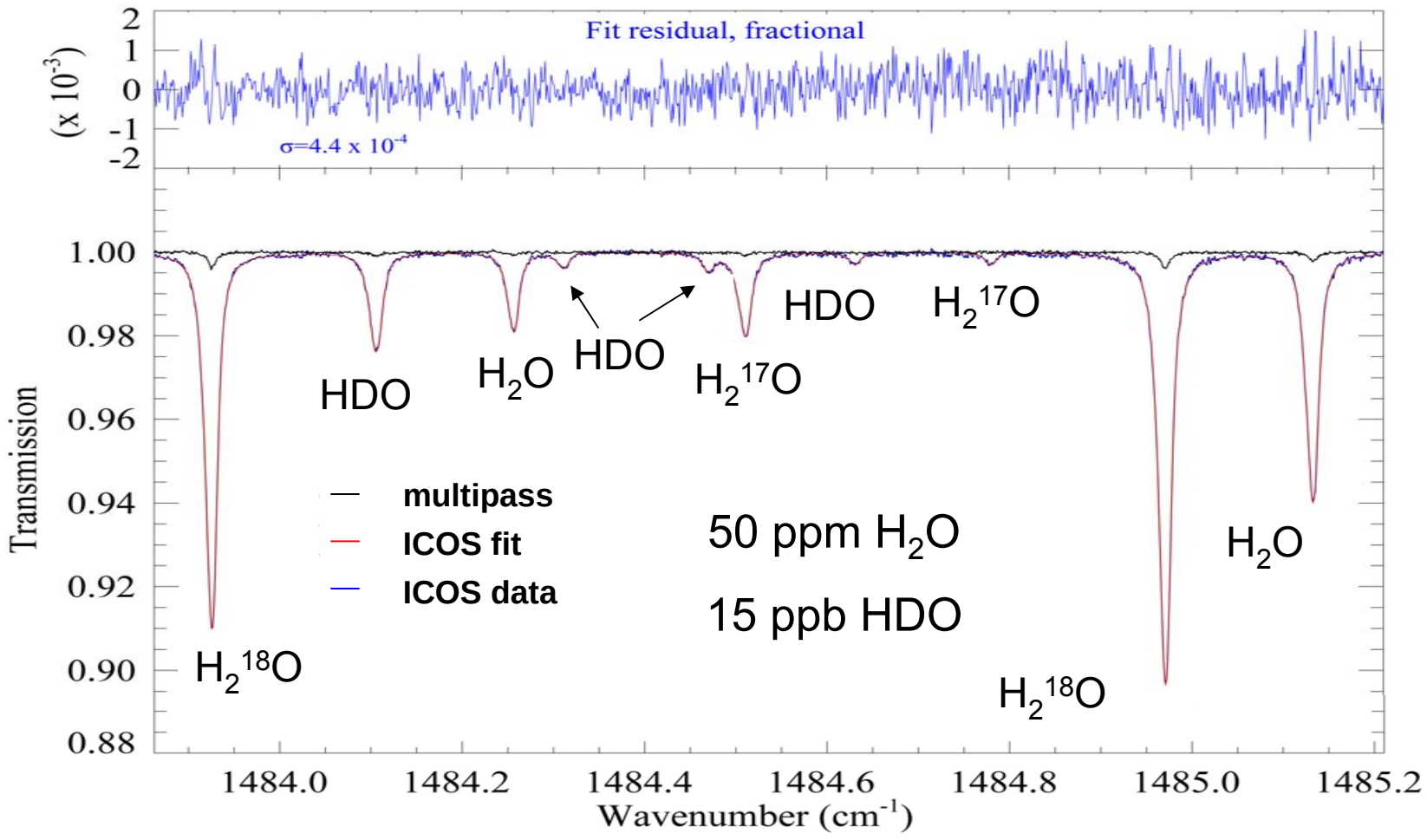
$$L_{eff} = \frac{L}{1-R}$$

$$L_{eff} = \frac{L}{1-0.9998} = 5000L$$

- New program funded by NASA (part of the Instrument Incubator Program)
- Steady State cw transmission monitored
- Ideal for measuring multiple species
- **Substantial pathlength enhancement:** **4200 m**

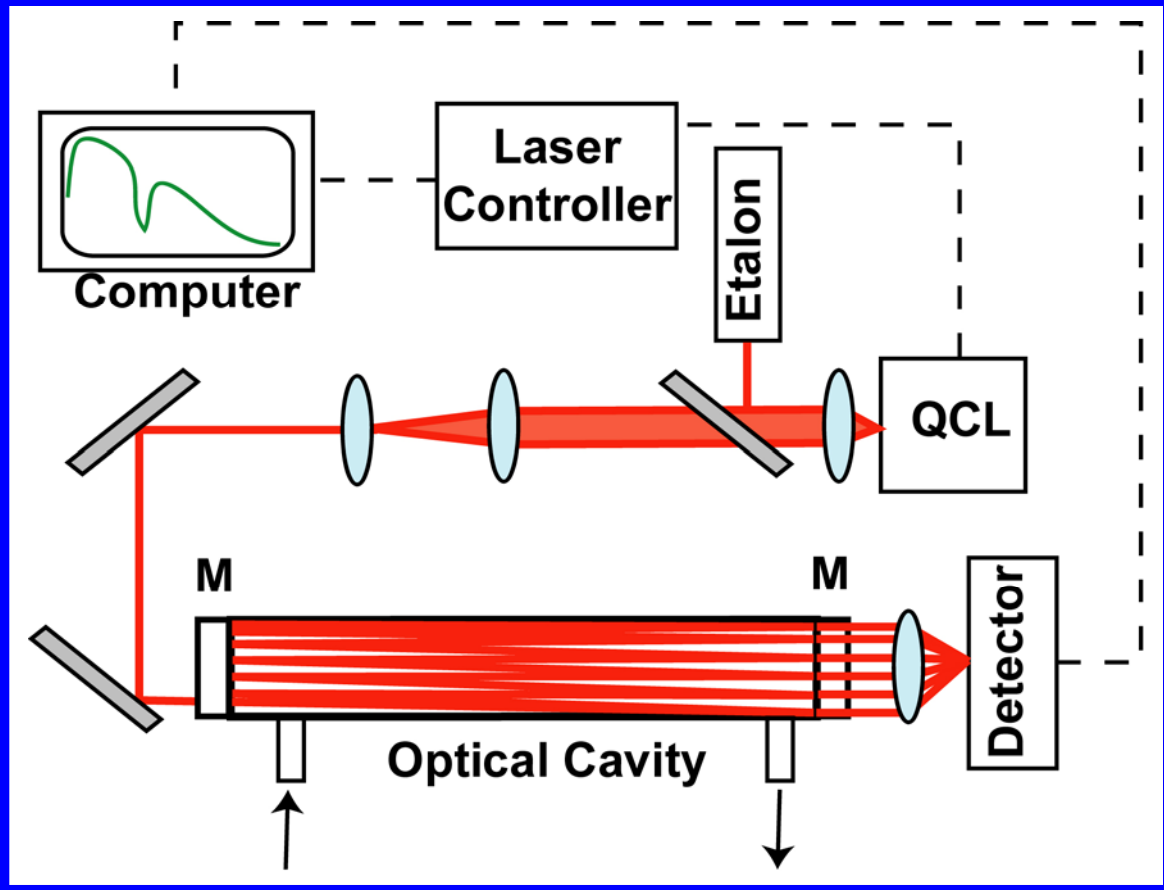
[1]Paul *et al.* Appl. Opt. **40**, 4904 (2001); Baer *et al.* Appl. Phys. B **75**, 261 (2002) .

ICOS sensitivity in comparison:

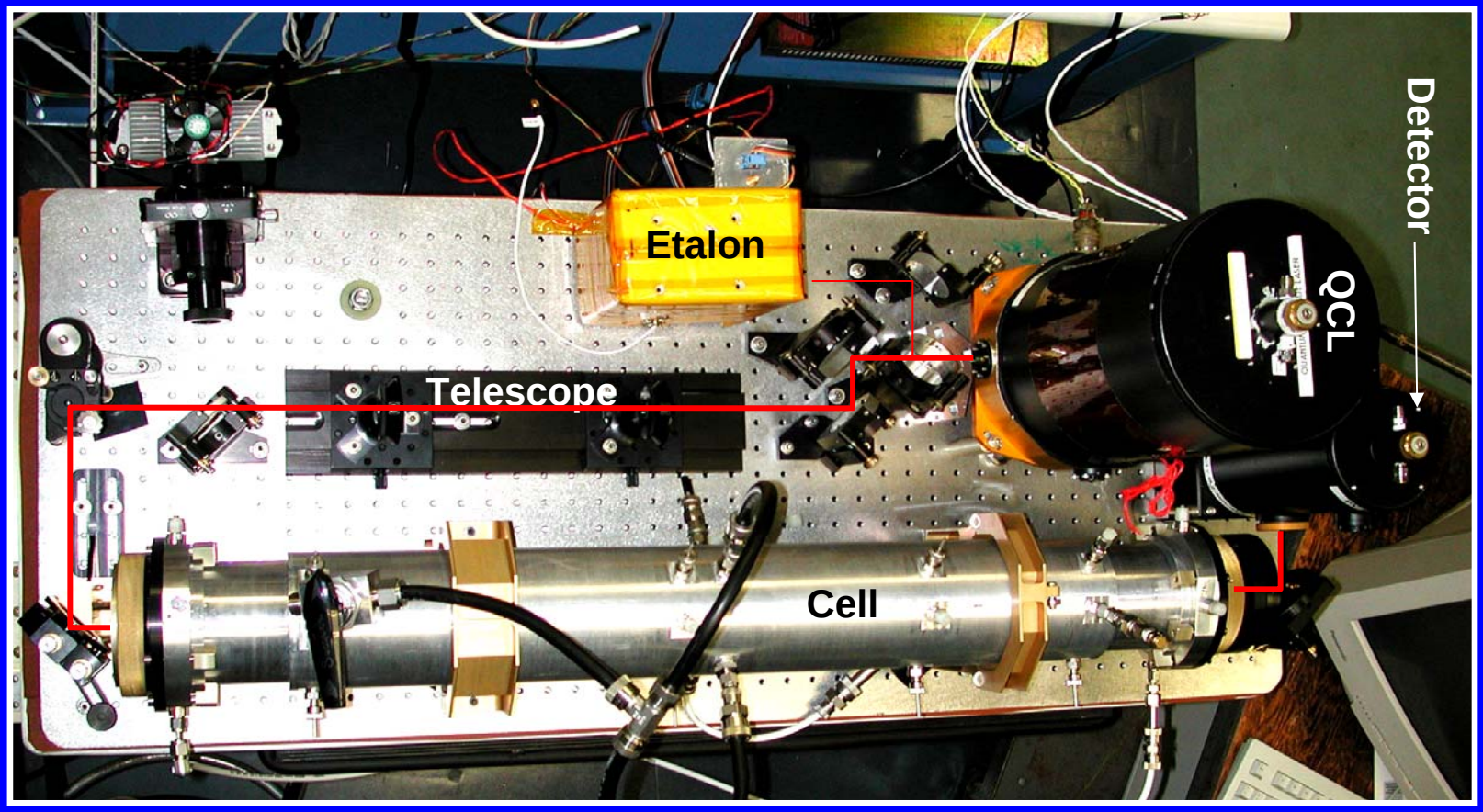


- Sensitivity in stratosphere: 55 ppt in 3s for HDO
- Observation of small changes in δD on a short timescale
- Improved analysis of fit artifacts

Harvard ICOS instrument



Harvard ICOS instrument



Robustness

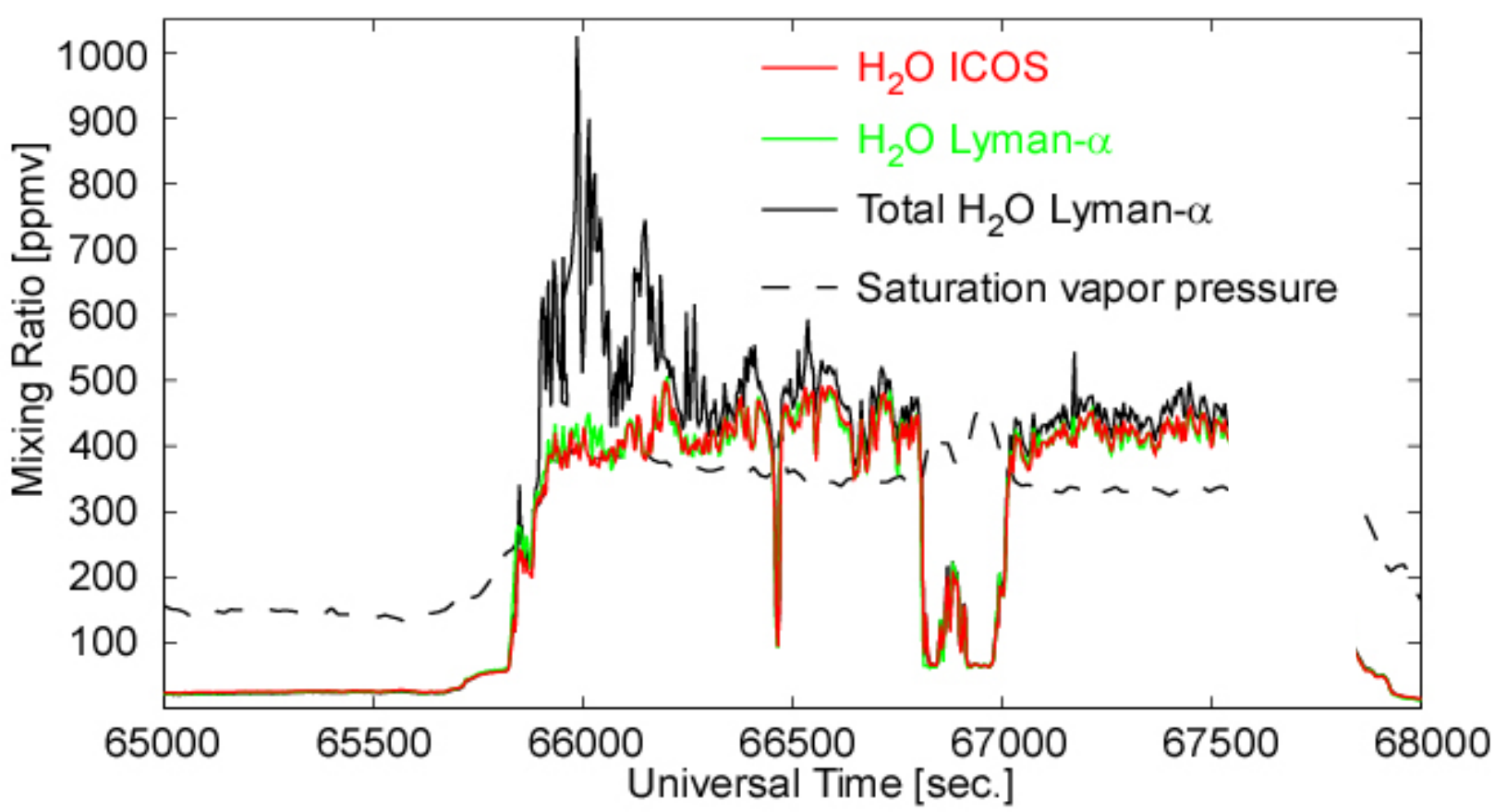
- Few movable parts; easy alignment
- Novel cavity design
  - Stable passive cavity; fixed mirrors

Contamination

- Sampling system:
  - Coated, electropolished
  - Minimal dead volumes

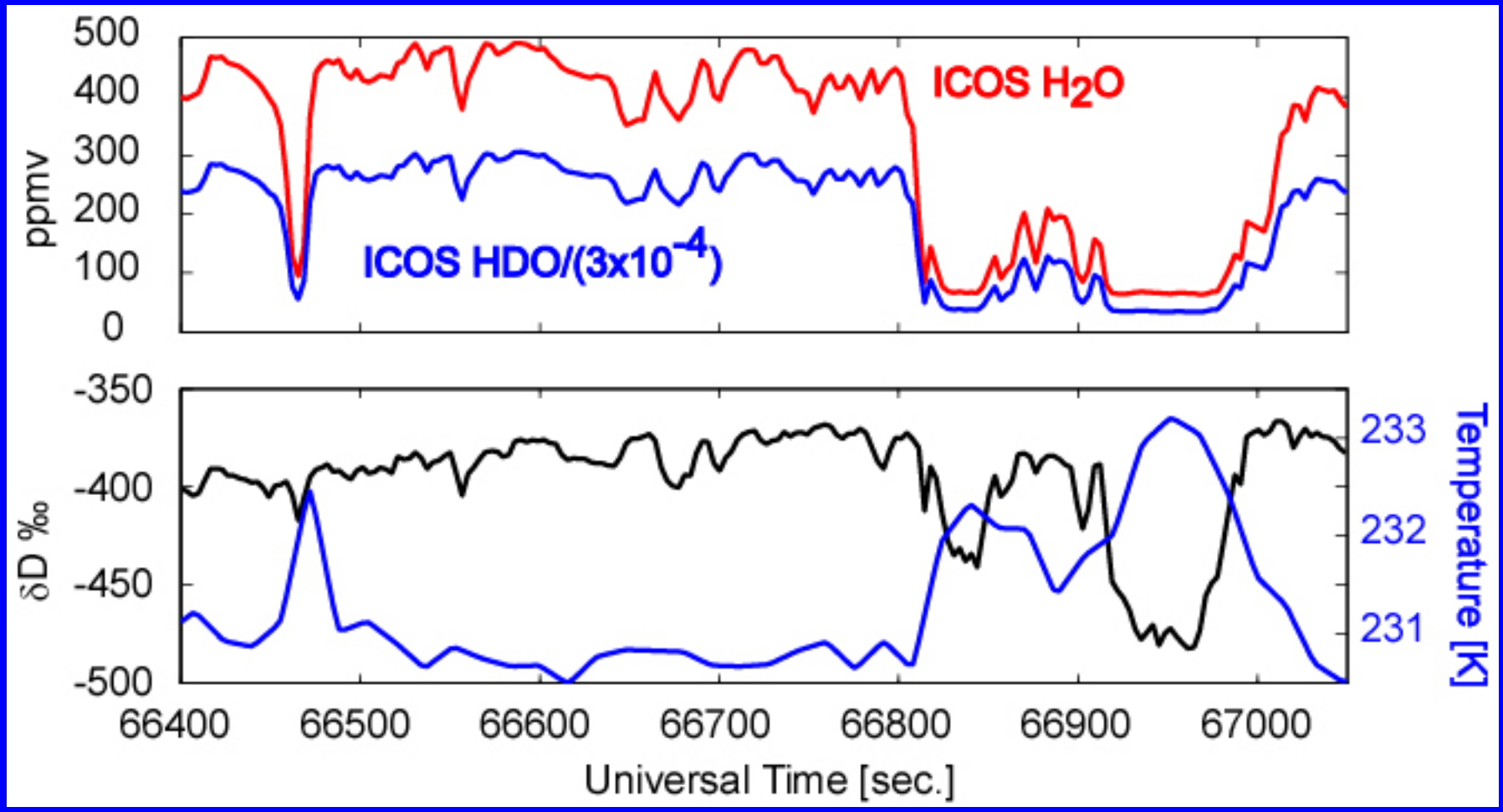
[1]Moyer, E.J., Sayres, D.S., Keutsch F.N. *et al.* in preparation (2005).

Harvard ICOS instrument: flight January 08, 2005



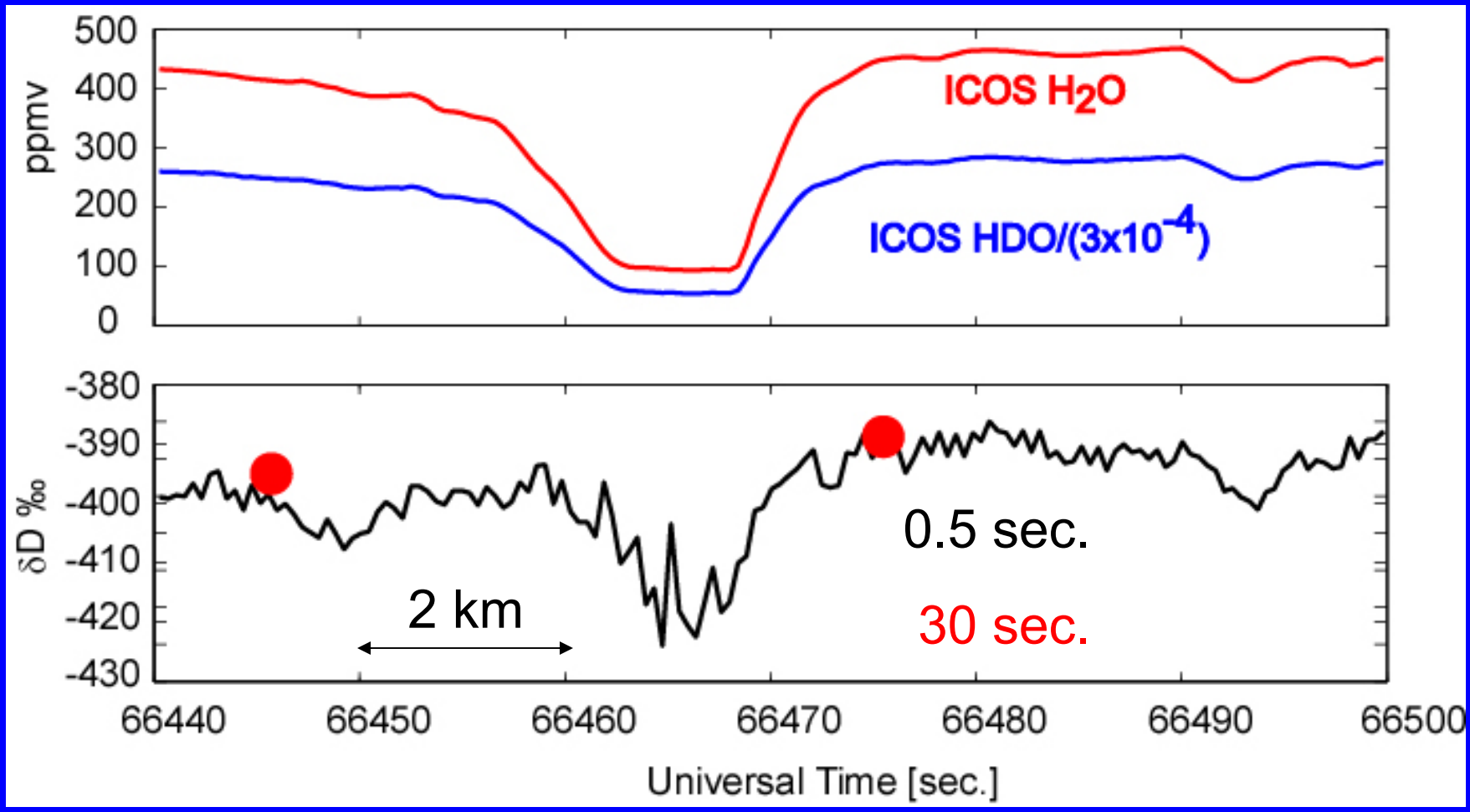
- 4 test flights
- Performance as in laboratory
- No evaporation of ice observed
- Fast time response

Harvard ICOS instrument: flight January 08, 2005



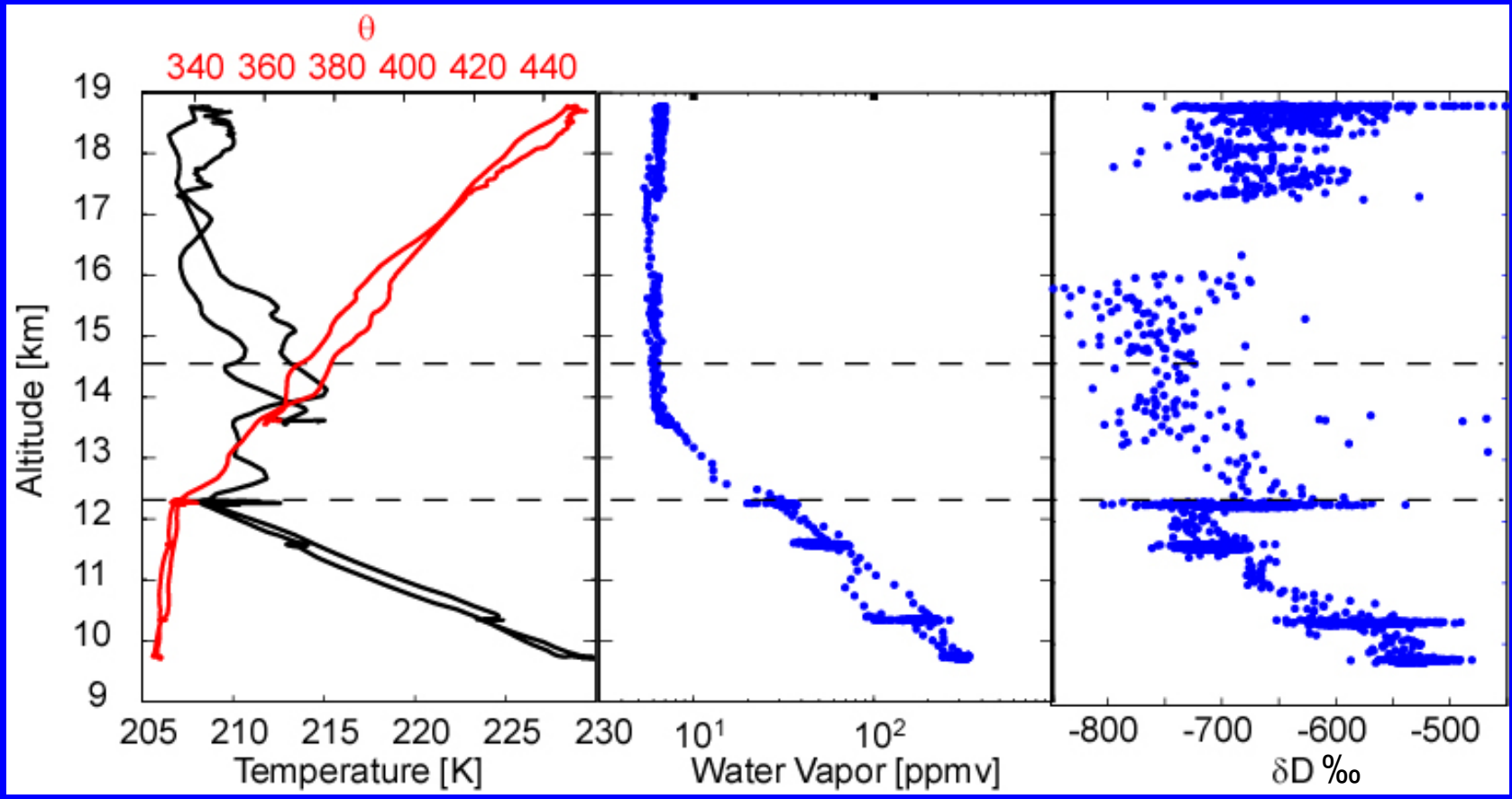
- Isotope ratio clearly provides needed tracer

Harvard ICOS instrument: flight January 08, 2005



- **Sensitivity allows fast measurements**

Isotopic fractionation: Preliminary results



- General profile resembles ATMOS, FIRS-2, Hoxotope data
- Variability at tropopause reflects atmospheric variability
- Analysis of variability $\Longrightarrow$ dehydration, transport mechanisms

[1]Moyer *et al.* Geophys. Res. Lett. **23**, 2385 (1996); Kuang *et al.* Geophys. Res. Lett. 30 Art. No. 1372 (2003), Webster, C.R. *et al.* Science **302**, 1742 (2003).

Conclusions

- Most sensitive airborne IR spectrometer
- Intercomparison with other instruments:
  - Fast time response
  - No evaporation of condensed phase
- Upgrades in progress:
  - Sealed cell
  - Pressure regulation system
- Water isotopologue (gas + condensed phase) measurements allow study of, e.g.:
  - Dehydration, transport, cloud microphysics and response to forcing
- Harvard ICOS instrument ready and available for Aura validation missions